CONSENSUS FORECASTING OF GLOBAL HORIZONTAL IRRADIANCE

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1. INTRODUCTION

Variable energy resources become a larger concern for utilities as their production increases as a percentage of total production. Solar energy production is now reaching a level that impacts grid operation. This increase in production relative to other energy resources requires that utilities better estimate the expected future solar energy production for near-term and day ahead operations. Improvements in solar energy forecasting will improve their operational efficiency and economic operation through reduction in uncertainty affecting their operations.

For forecasting beyond 6 hours ahead, Numerical Weather Prediction (NWP) models are the best forecasting resource. The primary alternative, forecast systems that rely on extrapolation of observed phenomena, have limited skill beyond the first few hours. These NWP models typically provide forecasts of downward shortwave radiation. Since the irradiance is the most correlated predictor of solar energy production, optimizing the forecast from NWP models is important.

This paper focuses on the use of consensus forecast technology to generate an optimized forecast of hourly average Global Horizontal Irradiance (GHI). The Dynamical Integrated foreCast (DICast) consensus forecast system, has been in use at the Research Application Lab at the National Center for Atmospheric Research (NCAR) for over 15 years. It considers forecasts from multiple NWP models and generates statistically improved forecasts relative to those ingredient forecast for many (but not all) forecast variables. This system has been used successfully for renewable energy wind forecasting (Myers 2011a, 2011b; Mahoney et al. 2012), road weather forecasting (Myers et al. 2001, 2002), as well as agricultural forecasting (Myers 2010). The goal of this work is to determine whether similar results are possible for the prediction of GHI.

The improved GHI forecasts are fed into other systems that derive Direct Normal Irradiance (DNI) and Diffuse Irradiance through empirical methods. These quantities can be used to calculate estimates of the Plane of Array Irradiance, that is, the solar irradiance striking a tilted solar panel. Empirical formulae that relate a subset of these predictors to the power generated can be applied to generate a power forecast for the end user.

2. OBSERVATIONS

GHI is the hemispherical radiation that hits a horizontal surface. Pyranometers are the most common solar instruments. They typically provide an instantaneous measurement that is sampled multiple times per hour. To develop a target for the consensus forecasting system, these samples must be averaged into hourly averages at each site to be consistent with the hourly average forecast target forecast. The consensus learning system attempts to learn how to generate forecasts that will match these observations. The consensus forecast system learning process will only operate at sites at which GHI is measured: at other sites, the system has no feedback to learn how to optimize its forecast.

For this project, observational GHI data from 66 Sacramento Municipal Utility District (SMUD) sites were used as a first test case. Although they are closely situated, it is valuable to have more than one or two sites in order to make more valid statistical calculations.

3. DATA PREPARATION

The first step in preparing the NWP data for DICast is to generate estimates of hourly average irradiance from each NWP model. This is more complicated than it first appears. None of the standard models directly provide hourly average irradiance.

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The first challenge is that the data from each model has a native temporal resolution. These are typically 1-hour or 3-hour resolution, or in the case of the North American Model (NAM), 1-hour early in the forecast period then 3-hour resolution later. In addition, the meaning of the irradiance variable varies from model to model. For example, in some models (NAM and the High Resolution Rapid Refresh - HRRR), instantaneous irradiance forecasts are provided. The Canadian Global Environmental Multi-scale (GEM) model provides total accumulated irradiance since the start of the forecast, while the Global Forecast System (GFS) provides total irradiance over the previous 3 hours at the 03Z, 09Z, 15Z and 21Z forecast times – and provides previous 6-hour totals at 00Z, 06Z 12Z and 18Z. All of these different definitions of the irradiance need to be converted into a common variable, chosen here to be an hourly average irradiance forecast. This requires specialized code for each model included in the forecast.

4. INTEGRATOR

The DICast integrator combines the forecasts from the ingredient NWP models to make a consensus forecast. It is designed to learn how to optimize that forecast consensus by comparing how well it did on its most recent forecast with the latest observation. The weights are nudged in the direction of the gradient in weight space to generate a new set of weights that are closer to the optimal weight vector. This optimal weight vector differs for each site and lead time. It also changes seasonally. The most recent forecasts from each component NWP model are combined using this set of weights to produce forecasts specific to each site and lead time.

5. RESULTS

The forecast from the GFS, GEM, NAM and HRRR models were integrated to generate forecasts for the 66 SMUD sites for the initial test period of Oct 1, 2013 through Dec 31, 2013. The errors of each individual model's forecasts were compared to the DICast errors at each site. For statistical significance, the errors from all the sites were aggregated to calculate an overall RMSE for each forecast at each lead time. The results are shown in Figure 1.

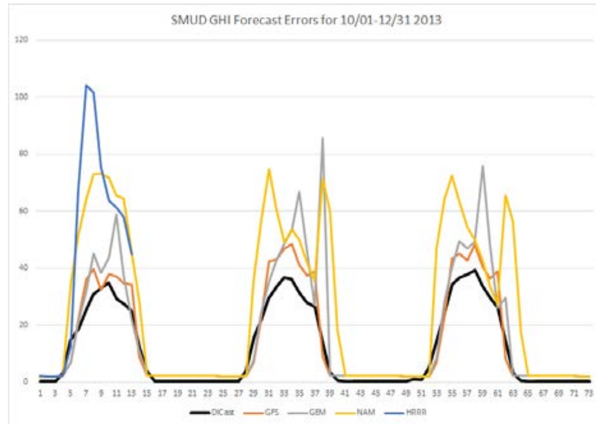

Figure 1: RMSE of GHI forecasts from individual models compared to DICast at SMUD sites. All forecasts were made from the latest model data available at 12Z (4AM PST) and the DICast integration of those model runs. Errors were calculated for forecasts generated during the 3 month period 10/01-12/31 2013. The horizontal axis shows lead time in hours. The vertical axis shows errors in W/m^2.

The DICast integrated forecasts produce significantly reduced errors when compared to forecasts based on any single model. The exception is near sunrise and sunset where other models are sometimes better. The GFS forecast is the best of the ingredient forecasts over this time period. If the daytime errors are summed for each forecast and compared, DICast produces errors that are, on average, 17% lower than the GFS on the current day's forecast, and 11% better for both the day ahead and two day ahead forecast. The improvement over the other component models is even greater.

6. CONCLUSIONS

The consensus approach appears, based on this limited study, to produce a forecast that is statistically superior to all ingredient NWP forecasts. This finding validates our hypothesis that solar forecast variables could be improved through a consensus process, much like shown before for other forecast variables. Since the time range and geographic extent of the study was limited, these results are very preliminary. However, they are quite promising that this approach will yield improved forecasts beyond a few hours and that further investigation is warranted.

In the future we plan to expand our study to a more geographically diverse set of observing sites. In addition, more verification will be done to evaluate forecast skill on cloudy days.

7. REFERENCES

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8. ACKNOWLEDGEMENTS

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